A DISTORTION INSENSITIVE QUADRILATERAL FINITE ELEMENT BASED ON THE ASSUMED STRESS CONCEPT IN CLOUGH'S 1960 PAPER

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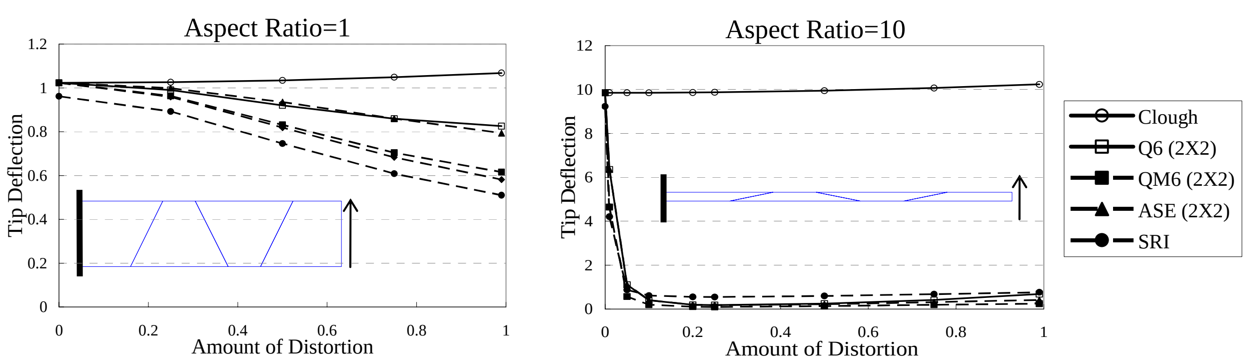
Clough [1] described an assumed stress rectangular element by directly computing the element stiffness matrix of a plane stress element from the five-parameter stress field in the local coordinates based on the 1956 paper by Turner et al [2]. In this paper, the element stiffness matrix of an arbitrary four-node quadrilateral is derived in a more general manner for plane elasticity problems, based on the assumption that the constitutive equation and the strain-displacement relationship are satisfied exactly following the above mentioned Clough's method. Carrying out the exact integration of the strain components leads to displacement functions containing the zero-strain-energy rigid body motions. The direct integration of the linear normal stresses results in a quadratic distribution of the displacement and failure of the standard patch test. Despite this violation, the nonconformity allows the element to become more flexible in bending, and more importantly insensitive to element distortion. Numerical examples show that this element is immune to distortion even for a large aspect ratio [3], which is the most essential quality in real analyses.



The method of stiffness matrix derivation for the four-node quadrilateral is also extended to higher order plane elements and three-dimensional solid elements. The six-node triangular and nine-node quadrilateral elements as well as tetrahedral and hexagonal solid elements are developed based on similar internal stress assumptions which satisfy the compatibility equations.

References

[1] R.W. Clough, "The Finite Element Method in Plane Stress Analysis," *Proc. 2nd Conference on Electronic computation*, p. 345-378, 1960.
[2] M.J. Turner, R.W. Clough, H.C. Martin, and L.J. Topp, "Stiffness and Deflection Analysis of Complex Structures", *Journal of the Aeronautical Sciences*, Vol. 23, No. 9, 1956.
[3] M. Sekiguchi, "A Study of Element Distortion for Membranes and Plates," Ph.D. Thesis, Dept. of Environmental and Ocean Engineering, The University of Tokyo, 2003.